Holt Instrument Laboratories

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DESIGNERS & MANUFACTURERS OF ELECTRONIC INSTRUMENTATION

SER. # 102

OPERATING AND SERVICING MANUAL

FOR

THERMAL VOLTAGE CONVERTER

MODEL II

HOLT INSTRUMENT LABORATORIES, INC.
Oconto, Wisconsin

DECEMBER 1968

CLAIM FOR DAMAGE SHIPMENT:

The instrument should be tested as soon as it is received. If it fails to operate properly, or it is damaged in any way, a claim should be filed with the carrier. Also, notify Holt Instrument Laboratories or the local representative immediately. A full report of the damage should be obtained by the claim agent and this report should be forwarded to us. We will advise you of the disposition to be made of the equipment and arrange for repair or replacement. Include model number and serial number when referring to this instrument for any reason.

WARRANTY:

Holt Instrument Laboratories warrants each instrument manufactured by them to be free from defects in material and workmanship. Our liability under this warranty is limited to servicing or adjusting any instrument returned to the factory for that purpose and to replace any defective parts thereof. Electron tubes, fuses, batteries and thermocouple modules are specifically excluded from any liability. This warranty is effective for one year after delivery to the original purchaser when the instrument is returned, transportation charges prepaid, and when upon our examination it is to our satisfaction defective. If the fault has been caused by misuse or abnormal conditions of operation, repairs will be billed at cost. In this case an estimate will be submitted before the work is started.

If any fault develops, the following steps should be taken:

1. Notify either the factory or the area Holt representative, giving full details of the difficulty, and include the model and serial numbers. Upon receipt of this information we will give you service data or shipping instructions.

2. On the receipt of shipping instructions, forward the instrument prepaid to the factory or the authorized repair station indicated in the instructions. If requested, an estimate of the charges will be made before the work begins if such work is not covered by warranty. All shipment of Holt Instrument Laboratories' equipment should be packed in a strong exterior container surrounded by two or three inches of shock absorbing material.

NOTICE:

The entire warranty on the Holt Model TVI Transfer Voltmeter is null and void if the seal of the thermocouple module shows evidence of having been opened or tampered with. If the thermocouple module is damaged, it must be returned to the factory for repair and calibration.

HOLT TECHNICAL BULLETIN

FIRST ISSUE

COAXIAL THERMAL CONVERTERS MODEL 11

NBS TRACEABLE

AC-DC DIFFERENCE STANDARDS

DESCRIPTION:

The Model 11 consists of five resistor modules and three thermoelement modules. Each thermoelement can be used with any resistor module resulting in eighteen separate and overlapping thermal voltage converter ranges.

The thermoelements, rated at 2.5 milliamperes, 5 milliamperes and 10 milliamperes, will deliver a nominal 7 millivolts at rated current. Each has an input resistance of approximately 400 ohms.

The resistor modules are identical, large diameter, chrome-plated canisters containing resistive elements. They are designed to provide low reactive effects, stable resistance characteristics and minimum thermal coefficient of resistance without external cooling requirements.

AC-DC difference data can be reported by Holt, traceable to the National Bureau of Standards, or the Model 11 may be tested and reported directly by NBS-Boulder, or NBS-Gaithersburg.

FREQUENCY RANGE – 3 MHz

VOLTAGE RANGE – 1200 VOLTS

EXCELLENT THERMAL STABILITY

TRUE RMS RESPONDING

HIGHEST ACCURACY

TECHNICAL SPECIFICATIONS

INDIVIDUAL MODULE AVAILABILITY:

Thermoelements:

P/N 90081A	2.5 ma rated current
P/N 90081B	5.0 ma rated current
P/N 90081C	10.0 ma rated current
Input Resistance:	400 Ω ±10%.
Output Resistance:	8 Ω ±10%.
Output Voltage:	7 mv ±12% at rated current.
DC Reversal Difference:	0.1% maximum.
Size: Diameter:	4" (overall including connector)
Length:	3½" (overall including connector)
Weight:	2 lb. each.

Resistors:

P/N 90080A	800Ω ±10%	12 max. voltage
P/N 90080B	3600Ω ±10%	40 max. voltage
P/N 90080C	11,600Ω ±10%	120 max. voltage
P/N 90080D	39,600Ω ±10%	400 max. voltage
P/N 90080E	119,600Ω ±10%	1200 max. voltage

Size: Diameter: 4"
Length: 7¾" (overall including connectors)
Weight: 4¼ lb. each

FULL SET - MODEL 11

One each of the following: Thermoelements (3) P/N 90081 A, B, C.
Resistor Modules (5) P/N 90080A, B, C, D, E.

Voltage Ranges:

Resistor P/N	W/TE P/N 90081A	W/TE P/N 90081B	W/TE P/N 90081C
No resistor	1.0 volt	2.0 volts	4.0 volts
90080A	3.0 volts	6.0 volts	12.0 volts
90080B	10.0 volts	20 volts	40 volts
90080C	30 volts	60 volts	120 volts
90080D	100 volts	200 volts	400 volts
90080E	300 volts	600 volts	1200 volts

SHORT SET - MODEL 11A

One each of the following: Thermoelements (2) P/N 90081 A, B
Resistor Modules (5) P/N 90080 A, B, C, D, E.

Voltage Ranges:

Resistor P/N	W/TE P/N 90081A	W/TE P/N 90081B
No resistor	1.0 volt	2.0 volts
90080A	3.0 volts	6.0 volts
90080B	10 volts	20 volts
90080C	30 volts	60 volts
90080D	100 volts	200 volts
90080E	300 volts	600 volts

AC - DC DIFFERENCE CALIBRATION:

Holt recommends that the full voltage application of these Thermal Converters be limited from 20 Hz to 3 MHz, and that higher frequency work be limited to the lower voltage ranges. These coaxial Thermal Voltage Converters may be used over the full frequency range from 5 Hz to 50 MHz. Actual AC-DC difference data at specific test points may be applied as correction factors to achieve the highest absolute accuracy. However, AC-DC differences may exceed ± 1% above 5 MHz, especially on the higher voltage ranges. The application of gross correction factors involves a certain amount of risk.

AC-DC difference correction factors may be achieved by direct comparison to known AC-DC difference standards. This may be accomplished by Holt Instrument Laboratories through comparison to NBS tested standards and a Holt certificate stating the correction factors will be furnished. Holt's charge for this service is cited below. These converters may be sent to either NBS-Gaithersburg or NBS-Boulder for their comparison to national standards. The customers should request NBS test services directly from the desired NBS facility. The limits of uncertainty, voltage and frequency ranges provided by these facilities are cited below:

NBS-Gaithersburg (Absolute via National Standards)
20 Hz to 20 kHz to 600 volts (± .003%)
20 kHz to 50 kHz to 600 volts (± .005%)

NBS-Boulder (Absolute via National Standards)
.03, .1, .3 and 1 MHz to 200 volts (± .05%)
3 and 10 MHz to 200 volts (± .10%)
30 MHz to 200 volts (± .20%)
50 MHz to 50 volts (± .5%)

Holt Instrument Laboratories (Absolute via NBS-traceable standards)
20 Hz to 20 kHz to 1000 volts (± .003%)
20 kHz to 50 kHz to 1000 volts (± .005%)
50 kHz to 100 kHz to 1000 volts (± .05%)
100 kHz to 10 MHz to 200 volts (± .10%)
10 MHz to 30 MHz to 50 volts (± .20%)

HOLT CALIBRATION OPTIONS:

Several calibration options are provided below which take into account various user requirements, Holt's primary capability and economy. The options cited economically provide for adequate data to allow customer intercomparison within his set to establish a complete table of correction factors. All calibration options may be omitted if the Thermal Voltage Converters purchased are going to be calibrated by either NBS facility.

Option I: Any customer selected test point (s) within Holt capability set forth above.
Option II:* Low frequency test points (24) from recommended calibration chart below (Model 11 only).
Option III:* Full-frequency test points (46) from recommended calibration chart below (Model 11 only).

*Note: Options II and III calibrations involves only 7 voltage ranges. The remaining 11 ranges are calibrated by the customer by intercomparison (bootstrapping) within the Model 11 set itself. See recommended intercomparison pattern on applications page.

Option II and III

Voltage Range	20 Hz	2 kHz	20 kHz	50 kHz	100 kHz	300 kHz	1 MHz	3 MHz
1 V	II,III	II,III	II,III	II,III	III	III	III	III
4 V	II,III	II,III	II,III	II,III	III	III	III	III
12 V	— —	II,III	II,III	II,III	III	III	III	III
40 V	— —	II,III	II,III	II,III	III	III	III	III
120 V	— —	II,III	II,III	II,III	III	III	III	III
400 V	— —	II,III	II,III	II,III	III	— —	— —	— —
1200 V	II,III	II,III	II,III	II,III	III	— —	— —	— —

Option IV**: Low frequency test points (20) from recommended calibration chart below (Model 11A only).
Option V**: Full frequency test points (41) from recommended calibration chart below (Model 11A only).

**Note: Options IV and V calibrations involve only six voltage ranges. The remaining six ranges are calibrated by the customer by intercomparison (bootstrapping) within the Model 11A set itself. (See recommended intercomparison pattern on applications page.)

Option IV, V

Voltage Range	20 Hz	2 kHz	20 kHz	50 kHz	100 kHz	300 kHz	1 MHz	3 MHz
2 V	IV, V	IV, V	IV, V	IV, V	V	V	V	V
6 V	— —	IV, V	IV, V	IV, V	V	V	V	V
20 V	— —	IV, V	IV, V	IV, V	V	V	V	V
60 V	— —	IV, V	IV, V	IV, V	V	V	V	V
200 V	— —	IV, V	IV, V	IV, V	V	V	V	V
600 V	IV, V	IV, V	IV, V	IV, V	V	— —	— —	— —

Option VI: (Individual voltage range) Low frequency test points (4) 20, 2k, 20k and 50kHz.
Option VII: (Individual voltage range) Full frequency test points (8) 20, 2k, 20k, 50k, 100k, 300k, 1M and 3 MHz.

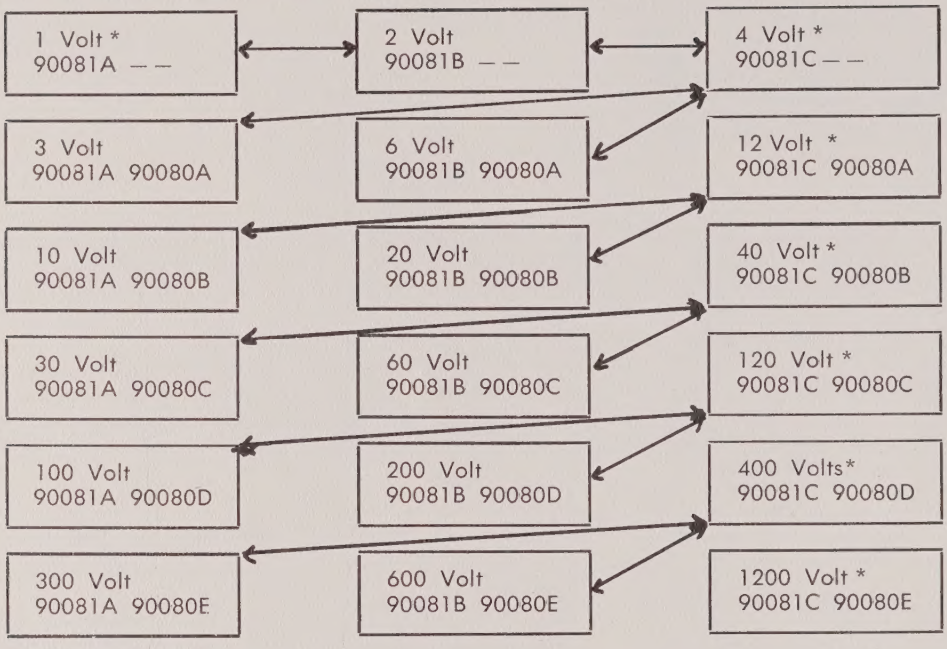
PRICES:

Individual Modules:
Thermoelements: (P/N 90081A, 90081B or 90081C) $100.00 ea.
Resistors: (P/N 90080A, 90080B, 90080C, 90080D or 90080E) $150.00 ea.
Full Set (Model 11): (3) thermoelements and (5) resistors $995.00
Short Set (Model 11A): (2) thermoelements and (5) resistors $895.00
Calibration Data (Holt):
Option I: Initial test point $50.00.
Each additional test point $33.00.
Option II: (24) low frequency test points $790.00 (Model 11 only).
Option III: (46) full frequency test points $1400.00 (Model 11 only).
Option IV: (20) low frequency test points $650.00 (Model 11A only).
Option V: (41) full frequency test points $1340.00 (Model 11A only).
Option VI: (4) low frequency test points $140.00 (any individual voltage range).
Option VII: (8) full frequency test points $270.00 (any individual voltage range).

Accessories:
Carrying Case and Cover P/N 8401-007 $50.00
(For Model 11 or 11A)
Thermoelement output cable P/N 84823 $12.00
(For use with Holt Model 375 Thermal Balance Unit.)
Thermoelement Output Cable P/N 82770 $12.00
(For use with Holt 6A Thermal Transfer Voltmeter)

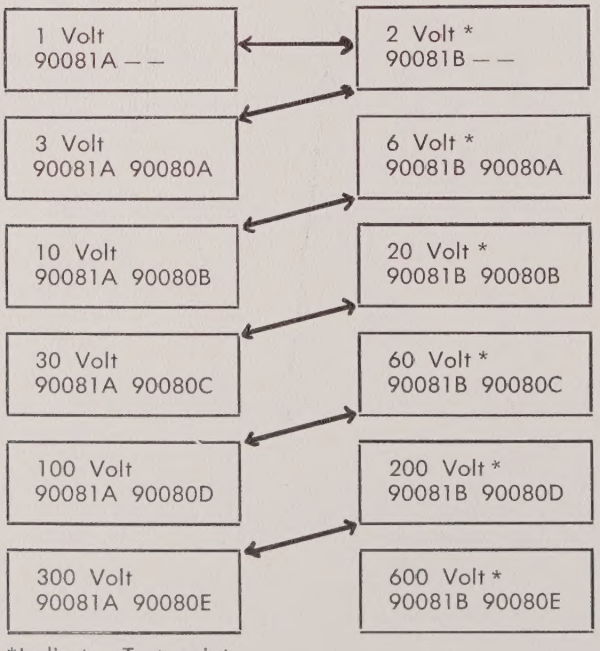
APPLICATIONS:

Intercomparison Pattern (Model 11):



*Indicates Test points.

Intercomparison Pattern (Model 11A):



*Indicates Test points.

Following the intercomparison, correction factors for each voltage range will be known. The appropriate elements may be connected to achieve any desired voltage range. The desired converter range may be connected in parallel with unknown voltmeters to determine the unknown's response to signals of constantamplitudeover the full frequency range.

TECHNICAL REPRESENTATIVE:

HOLT INSTRUMENT LABORATORIES
P. O. Box 230, Oconto, Wisconsin 54153
Phone (414) 834-2222

BULLETIN NO. 1908 Printed in U. S.

SECTION I
GENERAL DESCRIPTION

DESCRIPTION

The Holt Coaxial Model II Thermal Voltage Converters are used in measuring AC voltages in the audio and low radio frequency range with a high degree of accuracy. These converters are used to measure RMS voltages from 0.5 to 1200 volts in the frequency range of 5 Hz to 50 MHz in accordance with the technical specifications on the previous pages. The readings are made by an AC-DC transfer technique using either a stable DC or low frequency AC voltage source.

The Model II Thermal Converters consist of three thermoelement modules having current ratings of 2.5, 5 and 10 ma respectively, and five resistor modules. By using the appropriate combinations of these thermoelement and resistor modules, voltages from 0.5 to 1200 volts may be measured.

The Converter consists of a high vacuum UHF thermoelement which is connected in series with a low reactance resistor mounted concentrically in a coaxial line. The series resistance is a special sealed resistor. The higher voltage resistors have inner shields to reduce the effect of distributed capacitance from the resistor to the outer shield. These shields are adjusted and sealed at the factory. The resistor modules are provided with General Radio Type 874-B AC input connectors. The thermoelement module has a Type MS3102A10SL-4P output connector for the measurement of the thermal EMF. A thermoelement adapter assembly, Holt P/N 84980, is provided for connecting from the thermoelement module input to a GR Type 874B cable connection.

SECTION II
OPERATION

2.1 ADDITIONAL EQUIPMENT USED

Diagrams of an absolute AC voltage measurement and an AC-DC difference measurement are shown in Fig. 6.1 and Fig. 6.2 respectively. The necessary equipment used in these measurements consists of the following: a variable AC Power Source, a stable DC or Low Frequency Calibrated AC Voltage Source, a Thermocouple Potentiometer, Precision Voltbox, and a Precision DC Potentiometer. A brief explanation of each is given in the following paragraphs.

2.2 VARIABLE AC POWER SOURCE

The AC Power Source should have an output covering the voltage, frequencies and power at which tests are to be made. It is important that the short term output amplitude stability of the supply be high and that the unit be well shielded so there is little or no external RF energy.

Holt's audio and ultra-audio sources are ideal.

2.3 DC OR LOW FREQUENCY AC POWER SOURCE

The reference voltage may be either a DC supply or a calibrated low frequency AC power supply. In either case the short term stability must be good. If an AC voltage is to be measured, the output voltage of the reference supply must be known to an accuracy of at least equal to that desired in the final result.

If a frequency influence test is to be made, the source does not have to be calibrated. For these tests a Holt Model 631B, 630A, 325A or 323C Audio Voltage Standard is recommended because of its voltage stability and voltage resolution.

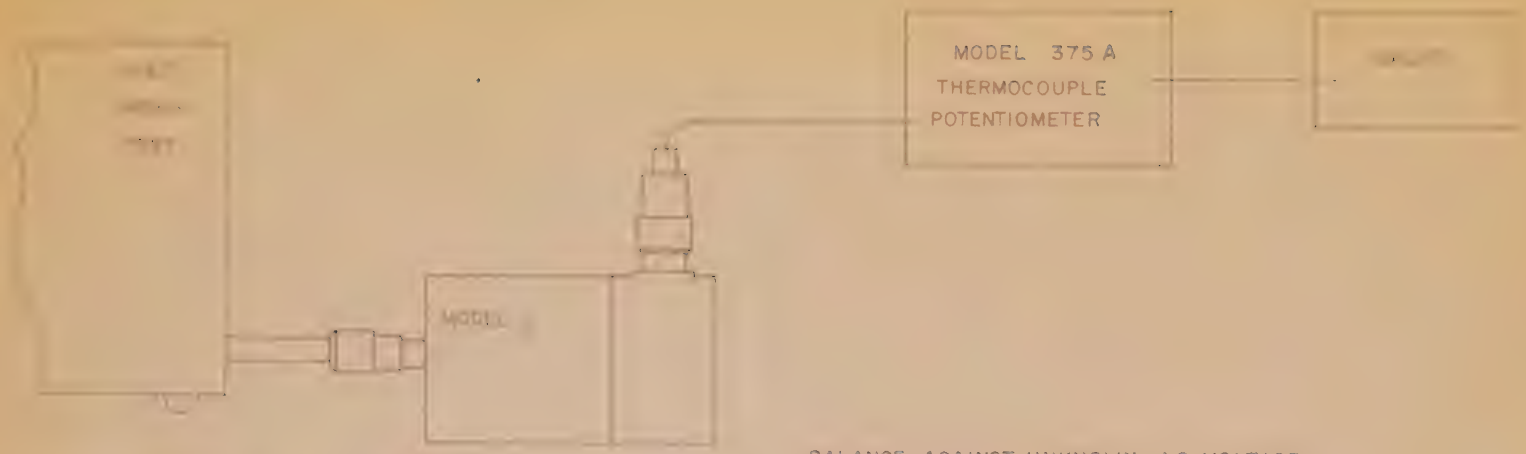
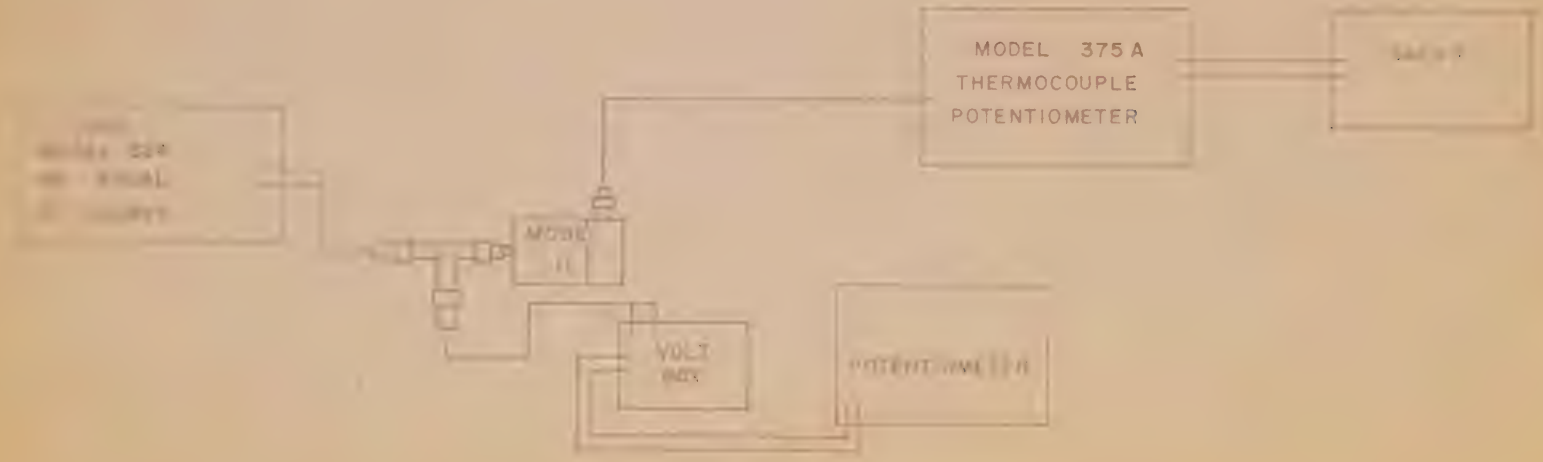


FIGURE 6.1 A

BALANCE AGAINST UNKNOWN AC VOLTAGE

ADJUST DC SOURCE TO SAME BALANCE



AC VOLTAGE MEASUREMENTS

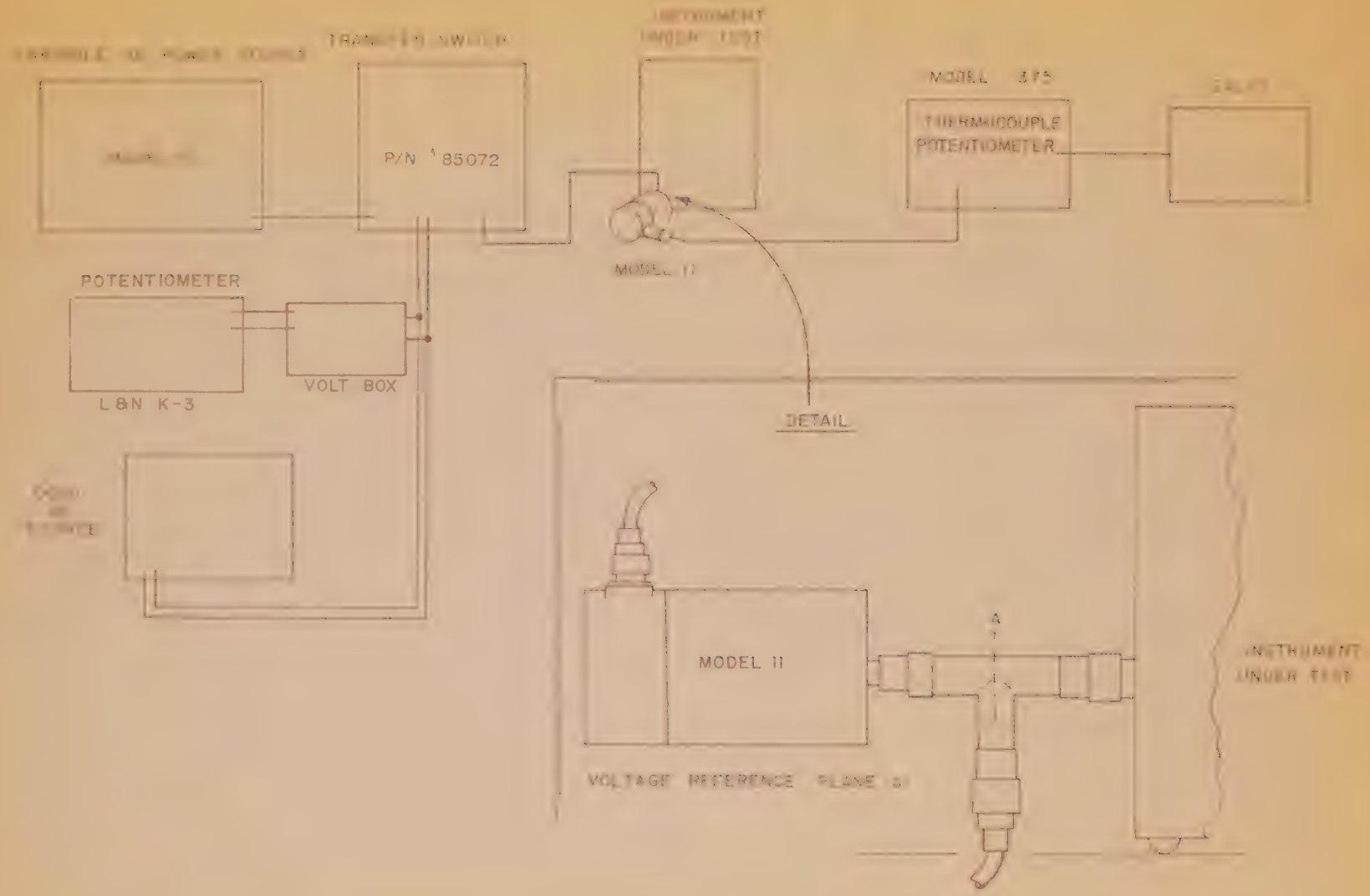


FIGURE 6.2 AC—DC DIFFERENCE

2.4 THERMOCOUPLE POTENTIOMETER

The Thermocouple Potentiometer may be a Lindeck Potentiometer such as a Holt Model 375 Thermal Balance Indicator. The Model 375 is used to measure the thermal EMF at the output terminals of the Model II Thermal Voltage Converters. When the thermal voltage converter is driven with its rated AC voltage, the DC voltage at the thermocouple output will be approximately 7 millivolts. The potentiometer used to measure this EMF must be designed to have a resolution and stability of the order of 0.1 microvolt for 10 ppm sensitivity. The Model 375 Thermal Balance Indicator is designed explicitly for this type of operation. It is constructed to minimize thermal EMF's in the circuit and to provide the greatest possible freedom from short term drift during the period of the transfer measurement.

2.5 VOLTBOX AND PRECISION POTENTIOMETER

To determine absolute values an accurate voltbox and precision potentiometer with a reference standard cell will be required.

SECTION III
OPERATIONAL TECHNIQUES

The operating procedure section of this manual has been divided into two parts. The first part is devoted to techniques used for rapid, convenient calibration of lower accuracy instruments such as vacuum tube voltmeters and oscilloscopes. The second part discusses the technique used in the high accuracy calibration of such instruments as thermocouple voltmeters, AC-DC difference tests of transfer voltmeters and intercomparison of thermal voltage converters.

3.1 GENERAL MEASUREMENT TECHNIQUES

It is important that the operator arrange the equipment interconnections and any metal to metal contacts between chassis so that there are no ground loops in the test setup. Most oscilloscopes and vacuum tube voltmeters have a direct connection between the common side of the input probe and the chassis ground. Therefore, these instruments should be isolated from the power line ground during calibration to prevent a loop being formed between the instrument under calibration and the signal ground of the AC calibrating system. The connection between the instrument under test and the AC voltage calibrating device, such as the Thermal Voltage Converter, is extremely critical, particularly at the higher frequencies and higher voltages. Since the coaxial lines used to bring the voltage from the variable AC power supply to the Thermal Voltage Converter and the instrument under calibration are terminated with very high impedances, they tend to perform as coaxial lines with open circuited terminations. Because of this effect, a

change of a few inches in the coaxial line length between the Thermal Voltage Converter and the instrument under test may cause a change of several percent in the instrument calibration. This is especially true at frequencies above 10 MHz.

3.2 RAPID CALIBRATION METHOD

The majority of the lower accuracy instruments have frequency ranges which extend from the lower audio range to the radio frequency spectrum. The operator will normally calibrate the low frequency section of the spectrum using an instrument such as the Holt Model 631B, 325A or 323C. This determines the full scale absolute voltage calibration and the meter movement linearity at the lower frequency end of this band. Then the operator uses the thermoelement Voltage Calibrator system to determine the flatness of frequency response from the audio frequency spectrum to given points in the high frequency spectrum. The techniques used for this type of calibration need not be highly accurate since the instruments being calibrated are usually specified at approximately 5% and accuracies of the order of 1/2% are adequate for this calibration.

3.3 OPERATIONAL TECHNIQUES FOR PRECISE MEASUREMENTS

The problems and difficulties involved in making precise AC measurements are many. As the accuracy is increased, the problems and difficulties increase exponentially. To overcome some of these problems, certain techniques and methods are helpful in the use of the Model II Thermal Converters. Some of the more useful are listed and explained in the following paragraphs.

The initial warmup period is a must. The length of time required is dependent on the converter used, but 5 to 10 minutes is generally sufficient. Due to the large thermal time constant, 30 seconds of warmup time should be allowed between the transfer and the actual reading so that the converter can reach its original state.

There are many calculations and corrections used in this manual. To avoid errors and inaccuracies, certain sign designations must be strictly adhered to throughout all the measurements. These sign designations are as follows: a positive (+) galvanometer reading is a galvanometer deflection which indicates an increase in input voltage. A plus (+) sign in the converter correction and in the calculated absolute readings indicates that more input voltage is required at high frequency than at DC to produce the same indication on the instrument under test.

The drift measurement should be small and preferably less than the desired accuracy. A large drift measurement will reduce the accuracy of the readings. Large drift readings are generally caused by insufficient warmup time or input voltage changes.

The drift correction as applied to the measurements in this manual is only valid if the voltage stability of the AC supply is better than the amount of drift in the instrument under test. The drift is assumed to be linear and in a constant direction during the period of the readings. The drift correction is subtracted algebraically in the calculations in this manual.

Above 10 MHz special emphasis should be placed on shielding and ground connections. Special care must be taken to prevent stray RF energy from entering the measuring system.

All power line operated units should be operated without a connection from chassis to line ground. All chassis should be connected together either through the shield of coaxial lines or by direct connections, but not both. Do not make multiple common connections. This common chassis connection should return to an earth ground. When this equipment is operated in a screen room, where a copper ground plane is available, the individual units should be bonded to the ground plane in accordance with normal screen room operating procedure.

CAUTION

Since any overload mechanism or circuitry would considerably reduce the frequency range of the Model II Converters, the Converters do not have overload protection. Therefore, it is extremely important that all necessary precautions be taken so as not to overload the converters. The maximum allowable overload is 150 percent of rated current. Above 150 percent damage may result to the converter.

If a converter is damaged it must be returned to the factory for repair and recalibration.

PROCEDURES

The three most important measurements using the Model II Converters are AC Voltage Measurement, AC-DC Difference Measurement and Frequency Influence Measurement. Other uses are similar, therefore the operating procedure will be the same. A detailed procedure is given below on these measurements. To simplify the procedure and to get the correct sequence the procedures will be listed in step form. A sample data sheet follows each procedure.

Before starting any of the following measurements refer to Section III, OPERATIONAL TECHNIQUES. The operator must then determine the approximate voltage range he wishes to measure and select from the set of three thermoelements and five resistors the appropriate combination of thermoelement and resistor for the voltage to be measured. Most

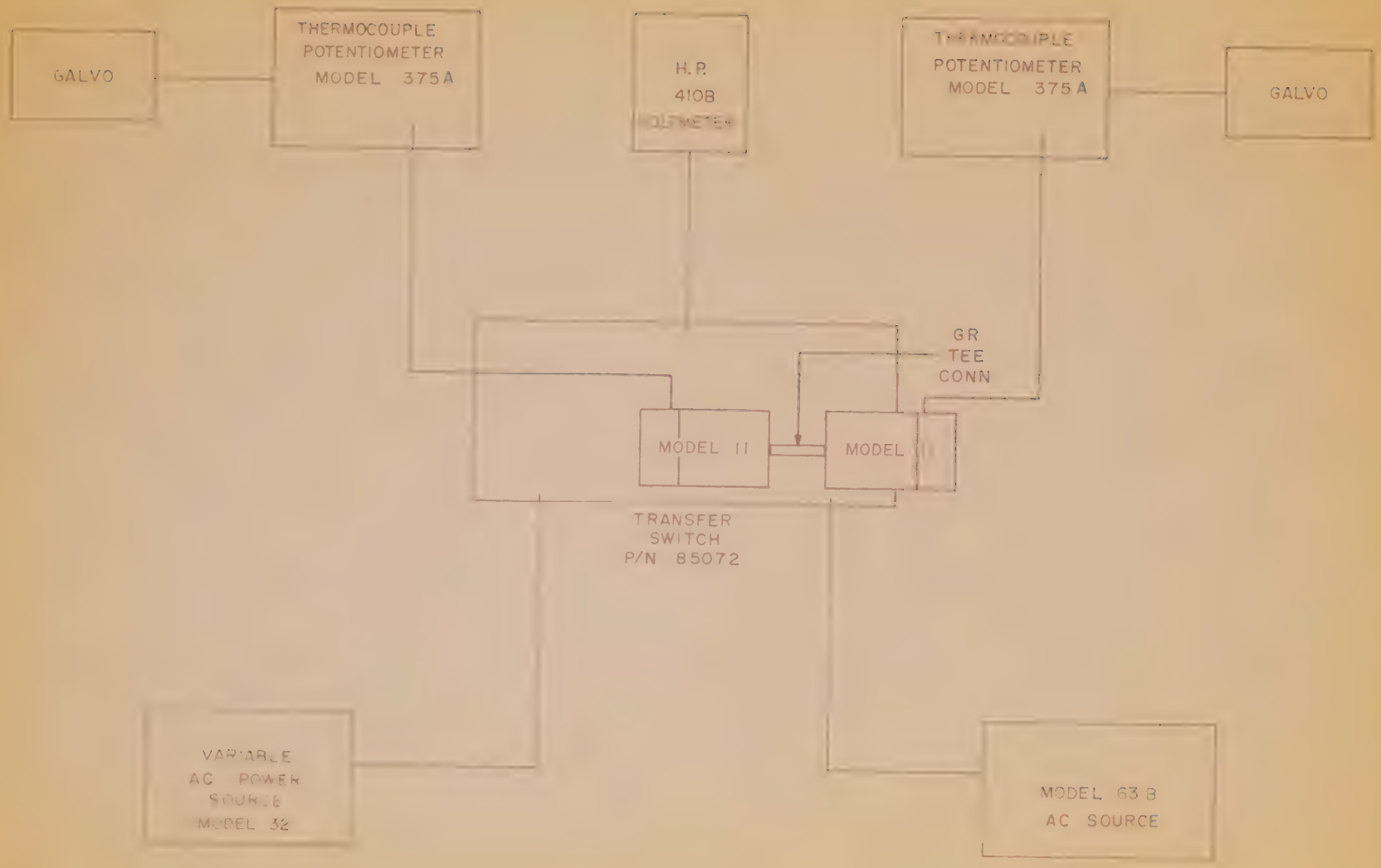


FIGURE 6.4 COMPARISON OF MODEL II THERMAL VOLTAGE CONVERTERS

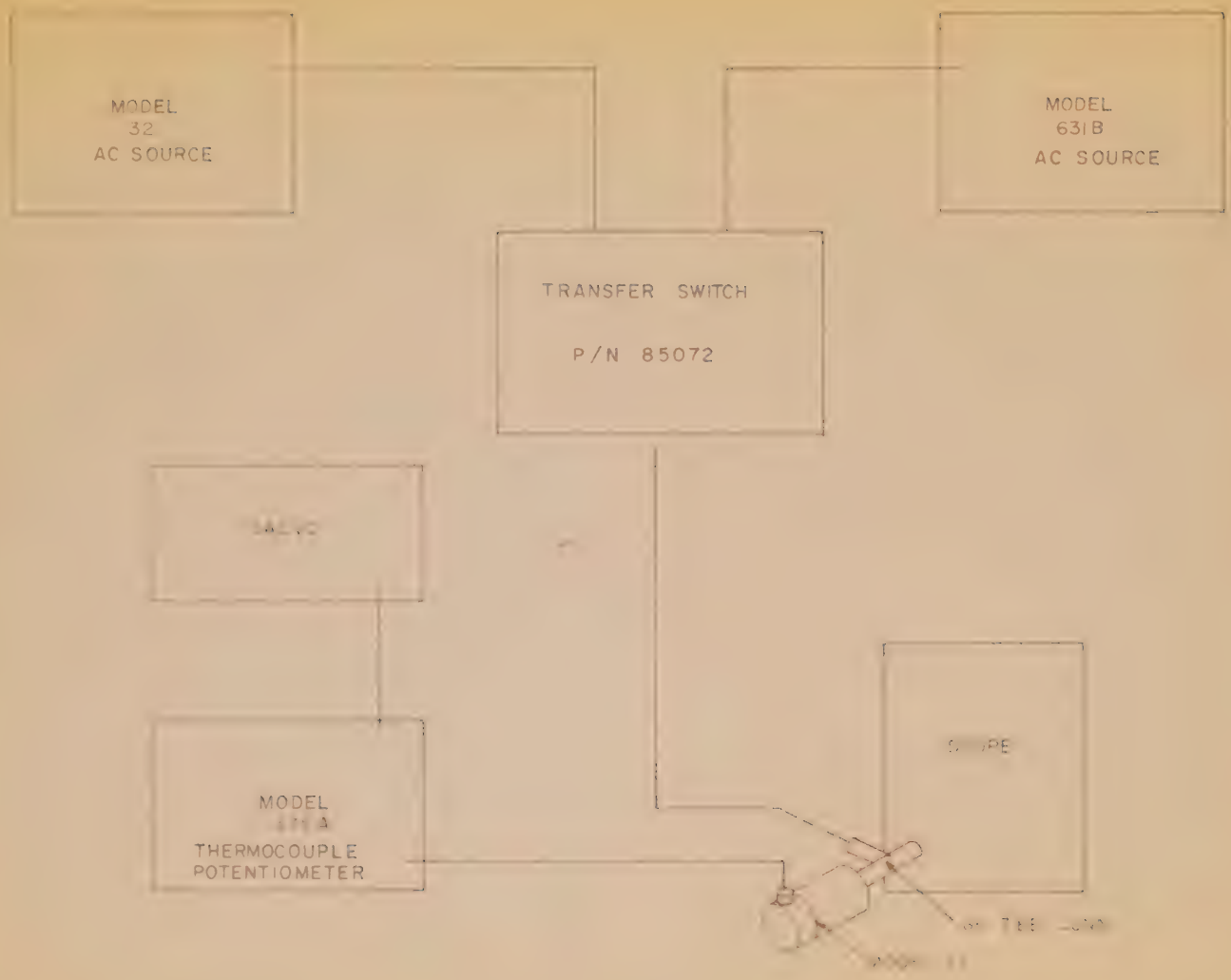


FIGURE 6 3 CALIBRATION SETUP FOR CALIBRATING AT FRONT PANEL TERMINALS

voltages in the range from 2 volts to 600 volts can be measured with more than one combination of resistor and thermoelement. The choice should be determined from one of two factors. If the thermoelement and resistor are chosen so that the current in the thermoelement is near the lower end of its specified range, the safety factor will be greater and there will be less chance of thermoelement burnout. However, at the low end of the thermoelement range the galvanometer resolution will be considerably reduced due to the square-law factor. Therefore, for highest accuracy, the resistor and thermoelement should be chosen so that the current will be near the high end of the thermoelement range. This combination will yield the highest resolution and best accuracy. However, the operator must exercise extreme care to avoid thermoelement burnout.

4.1 AC VOLTAGE MEASUREMENT

Absolute AC voltage can be measured using this procedure and applying the proper correction factors.

Basically this measurement of AC voltage is accomplished by a transfer technique in which the AC voltage causes a given output of a thermocouple. The AC voltage is then replaced with an amount of DC voltage that causes the same output of the thermocouple. This DC can then be measured accurately, and corresponds to the RMS value of the AC voltage.

Step 1) Use an AC Voltmeter to measure the approximate voltage. Using this measurement, select the proper voltage converter.

Step 2) Connect the circuit as shown in Fig. 6.1A.

Step 3) Apply the AC voltage that is to be measured. Adjust the balance controls on the thermocouple potentiometer to obtain a null on the galvanometer. Allow time for warmup. (Approximately 1 to 3 minutes.) After warmup, quickly reconnect to DC voltage, Fig. 6.1B, and adjust the DC voltage to obtain a null on the galvanometer without changing the balance control settings. This voltage is E_1. Increase the DC voltage by 0.1 percent to E_2. Note the direction and amount of deflection (d_1) of the galvanometer. Deflections of the galvanometer in this direction will be assigned a positive sign for the purpose of calculations outlined in this manual. The resolution (K_v) is determined by $K_v = \frac{E_2 - E_1}{d_1}$ where K_v is in volts per millimeter. Repeat this procedure several times and take the average. Once the resolution is obtained it will remain the same for this converter as long as the balance control settings are not changed by more than $\pm$ 2 percent.

NOTE: The choice of 0.1 percent voltage change is an arbitrary one. It can be any amount just so long as the galvanometer does not deflect off scale. For the Holt Model 375 Thermal Balance Indicator, a 0.1 percent voltage change provides on-scale readings for all converters from 33 percent to 120 percent of rated converter voltage, and also simplifies mathematical computations. For higher accuracy readings at frequencies to 50 kHz a deflection of 0.01% is recommended.

Step 4) Transfer to AC voltage and readjust the balance controls to obtain a null on the galvanometer.

Step 5) Disconnect from the AC voltage and connect to the DC voltage. Adjust the DC supply to obtain a null on the galvanometer without changing the balance controls settings. Measure the DC voltage (E_4) with the potentiometer.

Step 6) Reverse the polarity of the DC voltage and adjust the DC supply to obtain the null on the galvanometer without changing the balance control settings. Measure the reversed DC voltage (E_5), with the potentiometer.

Step 7) Transfer to the AC voltage and measure the thermal drift of source as well as the Converter, (d_4), in millimeters. The drift correction (e_3) is equal to 1/2 the drift (d_4) multiplied by the resolution (K_v) determined in Step 3. $e_3 = \frac{K_v d_4}{2}$

This drift correction is only valid if the voltage stability of the AC supply is better than the amount of drift in the Converter. Refer to Section III. OPERATIONAL TECHNIQUES.

Step 8) Calculate the average of the voltage readings from Step 5 and Step 6. $E_{AV} = \frac{E_4 - E_5}{2}$

Step 9) Repeat Steps 4 through 8 approximately 4 times to insure accuracy.

Step 10) Apply the correction (S_s) from the converter calibration chart and calculate the absolute AC voltage (AV_{abs}).

$$AV_{abs} = \frac{E_4 - E_5}{2} - \frac{K_v d_4}{2} \qquad (1 + \frac{S_s}{100})$$

The absolute AC voltage as measured in this procedure is the voltage at the input connector of the Thermal Converter. However, if very short connections are used between the converter and instrument under test corrections will be very small and for the most part can be disregarded.

The input capacitance of the Converter is small. Although this capacitance is small it tends to load the circuit at the higher frequencies. This additional loading may cause the measured voltage to be reduced in value.

For speed, convenience and increased accuracy, a test fixture incorporating switches for transferring from AC to DC and for reversing DC polarity is recommended. However, the effect of lead resistance and capacitance must be considered in the design of such a fixture.

SAMPLE DATA SHEET

FOR

AC VOLTAGE MEASUREMENT

Frequency 0.2 Megacycles

Converter Correction at 0.2 Megacycles $S_s = +0.01\%$

Voltage to be measured Approximately 95 Volts

The resolution (K_v) of the thermal converter is determined as follows: $K_v = \frac{E_2 - E_1}{d_1}$ in volts per millimeter where E_1 is the voltage for zero deflection of the galvanometer and E_2 is the voltage for a galvanometer deflection of d_1 millimeters.

The drift correction (e_3) of the thermal converter is determined as follows: $e_3 = \frac{K_v d_4}{2}$ in volts where d_4 is the thermal drift of the converter in millimeters.

The absolute AC Voltage (AV_{abs}) is determined as follows:

$$AV_{abs} = (E_{av} - e_3)\left(1 + \frac{S_s}{100}\right) = \frac{E_4 - E_5}{2} - \frac{K_v d_4}{2}\left(1 + \frac{S_s}{100}\right)$$

DC Potentiometer Voltage Readings		Average DC	Drift	Drift Correction	Absolute AC Voltage
+DC E_4	-DC E_5	$E_{ave} = \frac{E_4 - E_5}{2}$	d_4	$E_3 = \frac{K_v d_4}{2}$	$(E_{av} - e_3)(1 + \frac{S_s}{100})$
95.437	-95.427	95.432	+4	+0.00636	95.4351
95.440	-95.428	95.434	+3	+0.00477	95.4387
95.435	-95.422	95.429	0	0	95.4385
95.445	-95.430	95.438	+6	+0.00954	95.4375
				Total	381.7498

In this example $K_v = .00318$ v/mm.

No. of Tests 4

Average AV_{abs} 95.437

4-2 AC-DC DIFFERENCE

An instrument which responds to both AC and DC voltage can be calibrated by using DC voltage to determine the scale corrections and then by applying the AC-DC Difference the absolute value can be obtained at the desired frequency. The AC-DC Difference is the difference between the direct current or voltage and the alternating current or voltage required to produce the same indication on the instrument under test. The calibration factor obtained from this AC-DC test is known as the AC-DC Difference or "S" of the instrument under test at a particular frequency on a given voltage range. A positive "S" indicates that more AC voltage is needed at the high frequency than at DC to produce the same indication on the instrument under test.

Step 1) Connect the circuit as shown in Fig. 6.2.

Step 2) Gradually increase the high frequency voltage to the desired level, monitoring it with the RF Voltmeter. Adjust the balance controls on the Thermocouple Potentiometer to obtain a null on the galvanometer. Allow time for warmup. (Approximately 1 to 3 minutes). During warmup, transfer to DC voltage and adjust the DC to obtain a null on the galvanometer without changing the balance control settings. This voltage is E_1. Increase the DC by 0.1 percent to obtain E_2. Note the direction and deflection (d_1) of the galvanometer. Deflections of the galvanometer in this direction will be assigned a positive sign for the purpose of calculations outlined in this

manual. The resolution (K_p) is determined by $K_p = \frac{E_2 - E_1}{E_1 \; d_1} \times 100$ where K_p is in percent per millimeter. Repeat this procedure several times and calculate the average.

Step 3) Transfer to AC voltage and if necessary readjust the balance controls to obtain a null on the galvanometer. Note the exact reading of the instrument under test.

Step 4) Transfer to DC voltage and adjust the DC for the same reading on the instrument under test. Read the deflection (d_2) in millimeters on the galvanometer of the thermocouple potentiometer. If the galvanometer deflection is off scale use the alternate method for determining the AC-DC Difference.

Step 5) Reverse the DC voltage and adjust the DC for the same reading on the instrument under test. Read the galvanometer deflection (d_3) in millimeters.

Step 6) Transfer to AC voltage and adjust the AC for the same reading on the instrument under test. Measure the thermal drift of the converter and instrument (d_4) in millimeters.

Step 7) Calculate the average of the readings from Step 4 and Step 5. $\left(\frac{d_2 + d_3}{2}\right)$

Step 8) Apply correction (S_s) from the converter correction chart and calculate the absolute AC-DC Difference.

$$S_x = -K_p C_d + S_s = -K_p \left[\left(\frac{d_2 + d_3}{2}\right) - \frac{d_4}{2}\right] + S_s$$

Step 9) Repeat Steps 3 through 8 approximately 4 times to insure accuracy. Use the average of these four values of S_x.

SAMPLE DATA SHEET

FOR

AC-DC DIFFERENCE

Frequency 0.3 MHz

Converter Correction at 0.3 MHz S_s = +0.12%

The resolution (K_p) of the thermal converter is determined as follows: $K_p = \frac{E_2 - E_1}{E_1 d_1} \times 100$ in percent per millimeter where E_1 is the voltage for zero deflection of the null detector and E_2 is the voltage for a null detector deflection of d_1 millimeters.

The corrected difference (C_d) is determined as follows:

$C_d = \frac{d_2 + d_3}{2} - \frac{d_4}{2}$ in millimeters

where d_2 and d_3 are the null detector readings when +DC and -DC voltage is applied to the converter and instrument under test and d_4 is the null detector reading for the thermal drift of the converter.

The absolute AC-DC Difference (S_x) of the instrument under test is determined as follows:

$$S_x = -K_p C_d + S_s = -K_p \left(\frac{d_2 + d_3}{2} - \frac{d_4}{2}\right) + S_s$$

Null Detector Difference Readings		Average Difference Readings	Drift	Corrected Difference Readings (C_d)	Absolute AC-DC Difference
+DC d_2	-DC d_3	$\frac{d_2 + d_3}{2}$	d_4	$\frac{d_2+d_3}{2} - \frac{d_4}{2}$	$-K_p C_d + S_s$
+ 9	+11	+10	+2	+9.0	+0.030
+ 8	+10	+ 9	-1	+9.5	+0.025
+ 7	+ 9	+ 8	0	+8.0	+0.040
+11	+13	+12	+5	+9.5	+0.025
				Total	+0.120

In this example K_p = .01 %/mm.

No. of Tests 4

Average S_x +0.030%

c. AC-DC DIFFERENCE (Alternate Method)

This procedure is the same as the AC-DC Difference in Section 4-2 except that it is used to measure larger AC-DC differences.

The alternate method for determining the AC-DC difference may be simplified by first determining the DC reversal $\frac{(+DC) - (-DC)}{2}$ of the converter and also of the instrument under test. By applying the DC reversal corrections only one DC voltage reading would have to be taken on the converter (E_7) and one on the instrument under test (E_6). CAUTION: This DC reversal may change if the converter is subjected at any time to more than 150 percent of rated current.

Step 1) Connect the circuit as shown in Fig. 2.

Step 2) Gradually increase the high frequency voltage to the desired level, monitoring it with the RF Voltmeter. Adjust the balance controls on the thermal balance unit to obtain a null on the null detector. Allow time for warmup. (Approximately 1 to 3 minutes.) During warmup, transfer to DC voltage and adjust the DC to obtain a null on the null detector without changing the balance control settings. This voltage is E_1. Increase the DC by 0.1 percent to obtain E_2. Note the direction and deflection (d_1) of the null detector. Deflections of the null detector in this direction will be assigned a positive sign for the purpose of calculations outlined in this manual. The resolution (K_p) is determined by

$K_p = \frac{E_2 - E_1}{E_2 d_1} \times 100$ where K_p is in percent per millimeter. Repeat this procedure several times. and calculate the average.

Step 3) Transfer to AC voltage and if necessary readjust the balance controls to obtain a null on the null detector Note the exact reading of the instrument under test.

Step 4) Transfer to +DC voltage and adjust the DC for the same reading on the instrument under test. This voltage is E_6. Reverse the polarity of the DC voltage and adjust the -DC for the same reading on the instrument under test. This voltage is $E_{6'}$.

Step 5) Adjust the -DC voltage to obtain a null on the null detector. This voltage is $E_{7'}$. Reverse the DC voltage and adjust the +DC to obtain a null on the null detector. This voltage is E_7.

Step 6) Transfer to AC voltage and adjust the AC for the same reading on the instrument under test. Measure the thermal drift of the converter (d_4) in millimeters.

Step 7) Calculate the average corrected difference.

$$C_{da} = 1 - \frac{E_6 - E_{6'}}{E_7 - E_{7'}} \times 100$$

and the drift correction $e_3 = \frac{K_p d_4}{2}$

Step 8) Repeat steps 3 through 7 approximately 4 times to insure accuracy.

Step 9) Apply the correction (S_s) from the converter correction chart and calculate the absolute AC-DC Difference.

$$S_x = C_{da} - e_3 + S_s = \left| 1 - \frac{E_6 - E_{6'}}{E_7 - E_{7'}} \right| \times 100 - \frac{K_p d_4}{2} + S_s$$

SAMPLE DATA SHEET

FOR

AC-DC DIFFERENCE
(Alternate Method)

Frequency 0.3 MHz

Converter Correction at 0.3 MHz $S_s = +0.2\%$

The resolution (K_p) of the thermal converter is determined as follows: $K_p = \frac{E_2 - E_1}{E_1 d_1} \times 100$ in percent per millimeter

where E_1 is the voltage for zero deflection of the null detector and E_2 is the voltage for a null detector deflection of d_1 millimeters.

The average corrected difference (C_{da}) of the instrument under test is determined as follows:

$$C_{da} = \left(1 - \frac{E_6 - E_{6'}}{E_7 - E_{7'}} \right) \times 100 \text{ in percent}$$

where E_6 and $E_{6'}$ are the DC voltages necessary to produce the same indication on the instrument under test and E_7 and $E_{7'}$ are the DC voltages necessary to balance the null detector.

The drift correction (e_3) of the thermal converter is determined as follows: $e_3 = \frac{K_p d_4}{2}$ in percent

where d_4 is the null detector reading of the thermal drift of the converter.

SAMPLE DATA SHEET

FOR

AC-DC DIFFERENCE
(Alternate Method)

The absolute AC-DC Difference (S_x) of the instrument under test is determined as follows:

$$S_x = C_{da} - e_3 + S_s = \left(1 - \frac{E_6 - E_{6'}}{E_7 - E_{7'}}\right) \times 100 - \frac{K_p d_4}{2} + S_s$$

Instrument Under Test Readings		Null Detector Rea . .		Average Corrected Difference	Drift	Drift Corr.	Absolute AC-DC Diff.
E_6	$E_{6'}$	E_7	$E_{7'}$	C_{da}	d_4	$\frac{K_p d_4}{2}$	$C_{da} - e_3 + S_s$
10.100	-10.104	10.001	- 9.999	-1.020	-2	-0.02	-0.800
10.110	-10.114	10.007	-10.005	-1.059	-5	-0.05	-0.809
10.098	-10.102	10.003	-10.001	-0.979	0	0	-0.779
10.100	-10.104	10.001	- 9.999	-1.020	+1	+0.01	-0.830
					Total		-3.218
					No. of Tests	4	
In this example K_p = .02					Average S_x		-0.805

FREQUENCY INFLUENCE MEASUREMENTS

Some AC instruments that do not respond to DC must be calibrated in terms of a frequency influence test. In such a test the absolute voltage calibration of the instrument is determined at some mid-band frequency (f_o), and a deviation (D_x) curve is determined and plotted. The magnitude and sign of D_x (in percent) are determined as follows; $D_x = \left(\frac{E_{abs}}{E_{ind}} - 1\right) \times 100$ where E_{ind} is the voltage indicated by the instrument under test at each cardinal point on each range, and E_{abs} is the absolute AC voltage applied to reach these points. The absolute AC voltage at some mid-band frequency (f_o) is determined by using the AC VOLTAGE MEASUREMENTS procedure in Section 4-1.

If the instrument is to be used at some frequency (f_1) not in the mid-band frequency range, a frequency response correction (S_{ab}) will have to be made. The S_{ab} is the percent correction that is applied to the indicated value of the instrument under test at some frequency (f_1) not in the mid-band frequency range, so that the corrected value equals the mid-band frequency (f_o) value. The S_{ab} of the instrument under test is determined by using this FREQUENCY INFLUENCE MEASUREMENTS procedure.

The absolute voltage at some frequency (f_1) not in the mid-band frequency range is determined as follows: $E_{abs} = E_{ind}\left(1 + \frac{D_x}{100} + \frac{S_{ab}}{100}\right)$, where E_{ind} is the indicated reading of the instrument under test at (f_1), D_x is the deviation of the instrument under test at (f_o), and S_{ab} is the frequency response correction of the instrument under test at (f_1).

Step 1) Connect the circuit as shown in Fig. 6.2., with the exception that the DC power supply will be replaced by an AC power supply.

Step 2) Gradually increase the voltage at (f_o) to the desired level on the instrument under test. This voltage is E_1. Allow time for warmup. (Approximately 5 to 10 minutes). After warmup, adjust the balance controls on the thermocouple potentiometer to obtain a null on the galvanometer. Increase the AC by 0.1 percent to E_2. Note the direction and deflection (d_1) of the galvanometer. Deflections of the galvanometer in this direction will be assigned a positive sign for the purpose of calculations outlined in this manual. The resolution (K_p) is determined by $K_p = \frac{E_2 - E_1}{E_1 d_1} \times 100$. This resolution is in percent per millimeter. Repeat this procedure several times and calculate the average resolution.

Step 3) Readjust the voltage to the desired level on the instrument under test. If necessary readjust the balance controls to obtain a null on the galvanometer.

Step 4) Transfer to (f_1) AC voltage and adjust the AC for the same indication on the instrument under test. Read the deflection (d_5) in millimeters. If the galvanometer deflection is off scale, use the alternate method for determining the Frequency Influence.

Step 5) Transfer to (f_o) AC voltage and adjust the AC for the same indication on the instrument under test. Measure the thermal drift of the converter in millimeters (d_4).

Step 6) Calculate the drift correction (C_d). $C_d = d_5 - \frac{d_4}{2}$

Step 7) Repeat steps 3 through 6 approximately 4 times to insure accuracy.

Step 8) Apply the corrections (S_{fo} & S_{f1}) from the converter correction chart and determine the frequency response correction (S_{ab}) of the instrument under test.

$S_{ab} = K_p C_d + S_{f1} - S_{fo} = K_p(d_5 - \frac{d_4}{2}) + S_{f1} - S_{fo}$

The frequency influence or frequency response correction (S_{ab}) that is determined using this procedure is not the same as the AC-DC difference (S_x). The S_{ab} that is determined from this procedure is a frequency response correction.

SAMPLE DATA SHEET

FOR

FREQUENCY INFLUENCE MEASUREMENTS

Midband Frequency $f_o = 5$ kHz

Converter Correction at 5 kHz $S_{fo} = +0.001\%$

Correction Frequency $F_1 = 2$ MHz

Converter Correction at 2 MHz $S_{f1} = +0.05\%$

The resolution (K_p) of the thermal converter is determined as follows: $K_p = \frac{E_{2p} - E_1}{E_1 \, d_1} \times 100$ in percent per millimeter where E_1 is the voltage for zero deflection of the galvanometer and E_2 is the voltage for a galvanometer deflection of d_1 millimeters.

The corrected difference (C_d) of the instrument under test is determined as follows: $C_d = d_5 - \frac{d_4}{2}$ in millimeters where d_5 is the galvanometer difference reading and d_4 is the thermal drift of the converter in millimeters.

The frequency response correction (S_{ab}) is determined as follows:

$$S_{ab} = K_p C_d + S_{f1} - S_{fo} = K_p \left(d_5 - \frac{d_4}{2}\right) + S_{f1} - S_{fo}$$

Galvanometer Difference Readings d_5	Drift d_4	Corrected Difference (MM) $d_5 - \frac{d_4}{2}$	Corrected Difference (%) $K_p(d_5 - \frac{d_4}{2})$	Absolute Frequency Influence $K_p C_d + S_{f1} - S_{fo}$
+10	+2	+9.0	+0.090	+0.139
+9	-1	+9.5	+0.095	+0.144
+8	0	+8.0	+0.080	+0.129
+12	+5	+9.5	+0.095	+0.144
			Total	+0.556
			No. of Tests 4	
			Average S_{ab}	+0.139%

In this example $K_p = .01\%/mm$.

4-5 FREQUENCY INFLUENCE MEASUREMENTS (Alternate Method)

This procedure is used when a large frequency response correction is to be determined. Refer to Section 4-4 for an explanation of frequency influence measurements.

Step 1) Connect the circuit as shown in Fig. 6.2., with the exception that the DC power supply will be replaced by an AC power supply.

Step 2) Gradually increase the voltage at (f_o) to the desired level on the instrument under test. This voltage is E_1. Allow time for warmup. (Approximately 5 to 10 minutes). After warmup, adjust the balance controls on the thermocouple potentiometer to obtain a null on the galvanometer. Increase the AC by 0.1 percent to E_2. Note the direction and deflection (d_1) of the galvanometer. Deflections of the galvanometer in this direction will be assigned a positive sign for the purpose of calculations outlined in this manual. The resolution (K_p) is determined by $K_p = \frac{E_2 - E_1}{E_1 d_1} \times 100$. This resolution is in percent per millimeter. Repeat this procedure several times and calculate the average resolution.

Step 3) Readjust the voltage to the desired level on the instrument under test. If necessary readjust the balance controls to obtain a null on the galvanometer.

Step 4) Transfer to (f_1) AC Voltage and adjust the AC for the same indication on the instrument under test. This voltage is E_8. Adjust the AC voltage to null

the null detector.

This voltage is E_9.

Step 5) Transfer to (f_o) AC voltage and adjust the AC for the same indication on the instrument under test. Read the thermal drift (d_4) of the converter in millimeters.

Step 6) Calculate the uncorrected difference (C_{du}) and drift correction (e_3).

$$C_{du} = \left(\frac{E_8}{E_9} - 1\right) \times 100 \qquad e_3 = \frac{K_p d_4}{2}$$

Step 7) Repeat steps 3 through 6 approximately 4 times to insure accuracy.

Step 8) Apply the corrections (S_{fo} & S_{f1}) from the converter correction chart and determine the frequency response correction (S_{ab}) of the instrument under test.

$$S_{ab} = C_{du} - e_3 + S_{f1} - S_{fo} = \left(\frac{E_8}{E_9} - 1\right) \times 100 - \frac{K_p d_4}{2} + S_{f1} - S_{fo}$$

The frequency influence or frequency response correction (S_{ab}) that is determined using this procedure is not the same as the AC-DC Difference (S_x). The S_{ab} that is determined from this procedure is a frequency response correction.

SAMPLE DATA SHEET

FOR

FREQUENCY INFLUENCE MEASUREMENTS
(Alternate Method)

Midband Frequency $f_o = 5.0$ Kilocycles

Converter Correction at 5.0 Kilocycles $S_{fo} = +.001\%$

Correction Frequency $f_1 = 5$ Megacycles

Converter Correction at 5 Megacycles $S_{f1} = +0.05\%$

The resolution (K_p) of the thermal converter is determined as follows: $K_p = \frac{E_2 - E_1}{E_1 d_1} \times 100$ in percent per millimeter where E_1 is the voltage for zero deflection of the galvanometer and E_2 is the voltage for a galvanometer deflection of d_1 millimeters.

The corrected difference (C_{du}) of the instrument under test is determined as follows: $C_{du} = \left(\frac{E_8}{E_9} - 1\right) \times 100$ in percent where E_8 is AC voltage necessary to produce the same indication on the instrument under test and E_9 is the AC voltage necessary to balance the galvanometer.

The drift correction (e_3) of the thermal converter is determined as follows: $e_3 = \frac{K_p d_4}{2}$ in percent where d_4 is the galvanometer reading of the thermal drift of the converter.

The Absolute Frequency Influence or frequency response correction (S_{ab}) of the instrument under test is determined as follows:

$$S_{ab} = C_{du} - e_3 + S_{fl} - S_{fo} = \left(\frac{E_8}{E_9} - 1\right) \times 100 - \frac{K_p d_4}{2} + S_{fl} - S_{fo}$$

Correction Frequency Voltages		Corrected Difference $\left(\frac{E_8}{E_9} - 1\right) \times 100$	Drift d_4	Drift Correction $\frac{K_p d_4}{2}$	Absolute Frequency Influence $C_{du} - e_3 + S_{fl} - S_{fo}$
E_8	E_9				
98.928	100.000	-1.072	+5	+0.0125	-1.0355
98.950	100.100	-1.149	+8	+0.0200	-1.1200
98.933	100.010	-1.077	+3	+0.0075	-1.0355
98.937	100.020	-1.073	+1	+0.0025	-1.0265
				Total	-4.2175
				No. of Tests	4
				Average S_{ab}	-1.054%

In this example K_p = 0.005%/mm.

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